



Demand Access System

**Maximum Allowable Error
Between TDRS SVs**



Outline

Introduction and Summary

MA Antenna Offpointing

TDRS Transition time

Doppler Correction



DAS Action Item # 138

‘TDRS State Vector Tolerance & Replan Loading’

- Statement:** Assess the maximum variation in TDRS state vectors that DAS could tolerate without initiating a total schedule re-plan. Assess the loading on DAS to do a major schedule re-plan due to TDRS state vector changes

- Opened:** 5/23/01

- Due Date:** 7/25/01

Notes:

1. These next few slides address only “TDRS SV Tolerance”
2. “Replan Loading” analysis will be addressed after the Resource Planning code has been implemented and tested



Issue Overview



- ❑ DAS uses ECON-provided TDRS SVs to generate TDRS ephemeris for:
 - Resource planning (TDRS transition timing using Visibility Service Legs (VSLs))
 - Beamforming (Beam pointing using direction cosines)
 - Demodulation (Doppler correction to aid tracking)
- ❑ If a new set of TDRS ephemeris must be used, then all user VSLs are affected and a total re-plan must be executed
- ❑ It is desirable to avoid this re-computation for current day operations; replan will always be performed for subsequent days
- ❑ Inaccurate TDRS ephemeris affects:
 - TDRS transition times
 - MA beamforming accuracy
 - Carrier tracking
- ❑ **Issue:** How much TDRS ephemeris can be tolerated before a replan is required for current day operations ?



Summary

- ❑ TDRS Ephemeris Error tolerance driven by MA beam pointing
- ❑ Maximum allowable TDRS ephemeris error will be set to 180 km
 - Limits MA Beamforming loss < 0.1 dB
- ❑ Maximum impact on TDRS Transition Timing < 1.9 secs
 - Acceptable within the 15 second transition tolerance required in the DAS SRD
- ❑ Maximum impact on Tracking Loop error (Doppler Correction) < 0.3°
 - 0.3° represents < 5% of phase error budget even for QPSK
 - Acceptable within the implementation loss allocated to the demod



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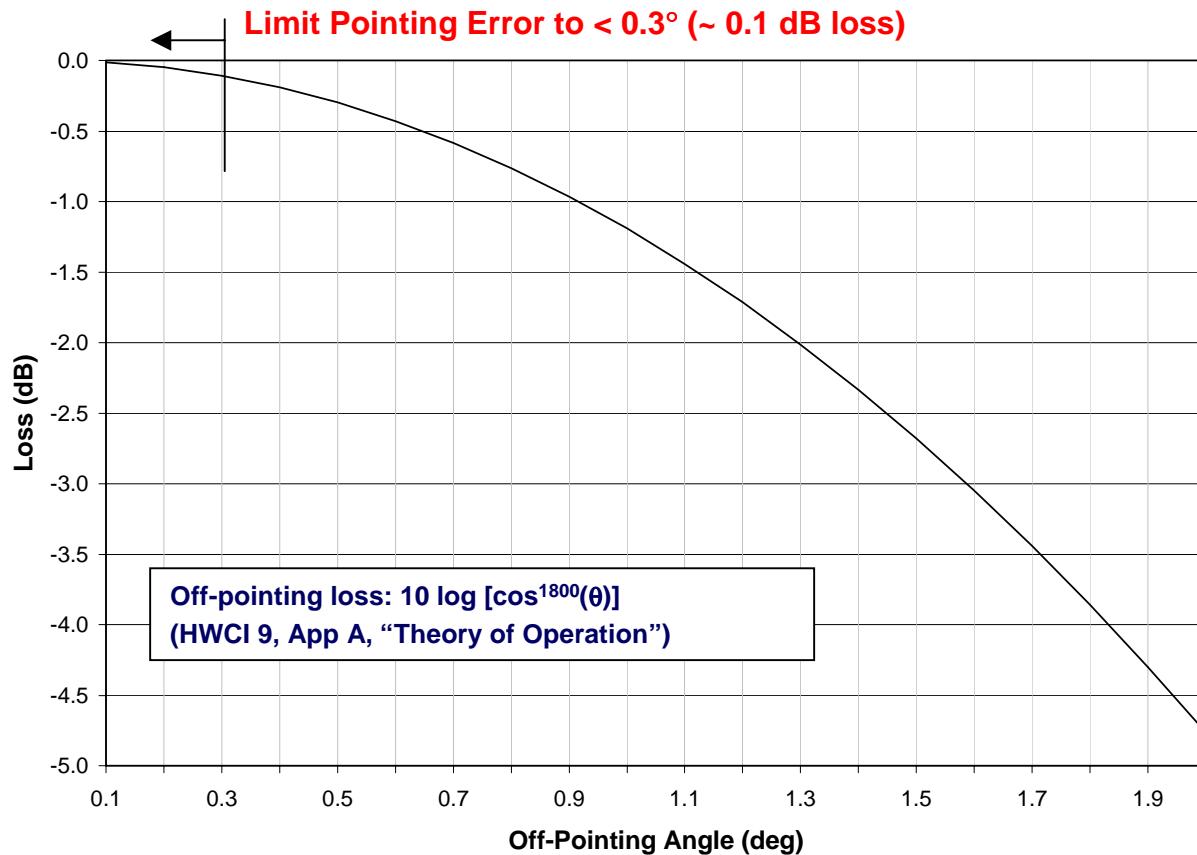
→ **MA Antenna Offpointing**

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MA Antenna Offpointing Loss





TDRS Orbital Information (GSFC MMFD Web Site*)

Satellite	Flight Number	SIC	SATID YYnumPA	Status Name	Longitudinal Box	Inclination and Change	Ground Terminal
TDRS-1 (A)	F-1	1300	8302602	049	49° West \pm 0.3°	10.8° ↑	White Sands
TDRS-3 (C)	F-3	1302	8809102	Zone of Exclusion	275° West \pm 0.5° or 85° East \pm 0.5°	5.4° ↑	Guam (GRGT)
TDRS-4 (D)	F-4	1303	8902102	East	41.2° West \pm 0.3°	3.1° ↑	White Sands
TDRS-5 (E)	F-5	1304	9105402	West	174.3° West \pm 0.1°	2.2° ↑	2 nd TDRSS
TDRS-6 (F)	F-6	1305	9300302	Spare	47° West \pm 0.1°	1.4° ↑	2 nd TDRSS
TDRS-7 (G)	F-7	1306	9503502	171	171° West \pm 0.5°	3.8° ↑	2 nd TDRSS
TDRS-8 (H)	F-8	1307	0003401	150	150° West \pm 0.5°	6.9° ↓	White Sands

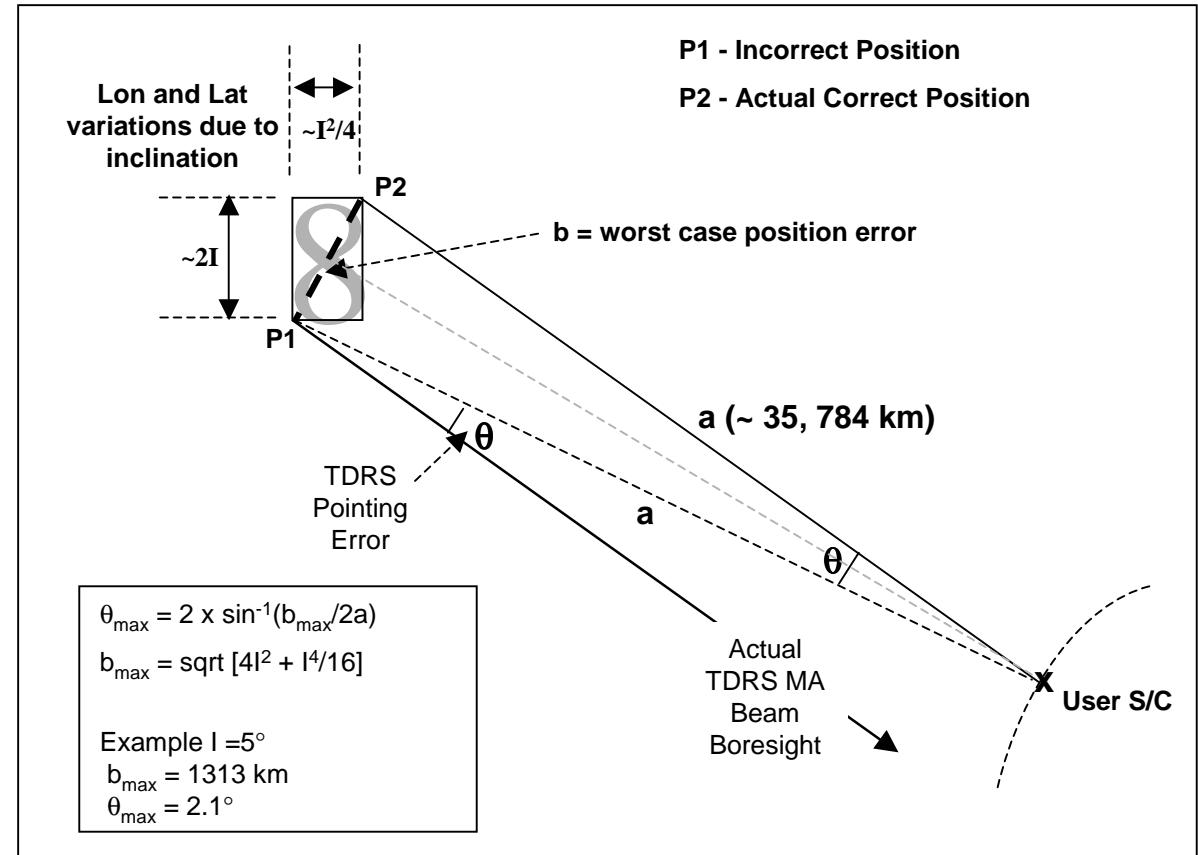
- TDRS Orbit Inclination may be as high as ~ 11° (i.e., F1)
- GEO Inclination Angle drift is ~ 0.86°/yr

* Mmfd.gsfc.nasa.gov/tdconst.jpg



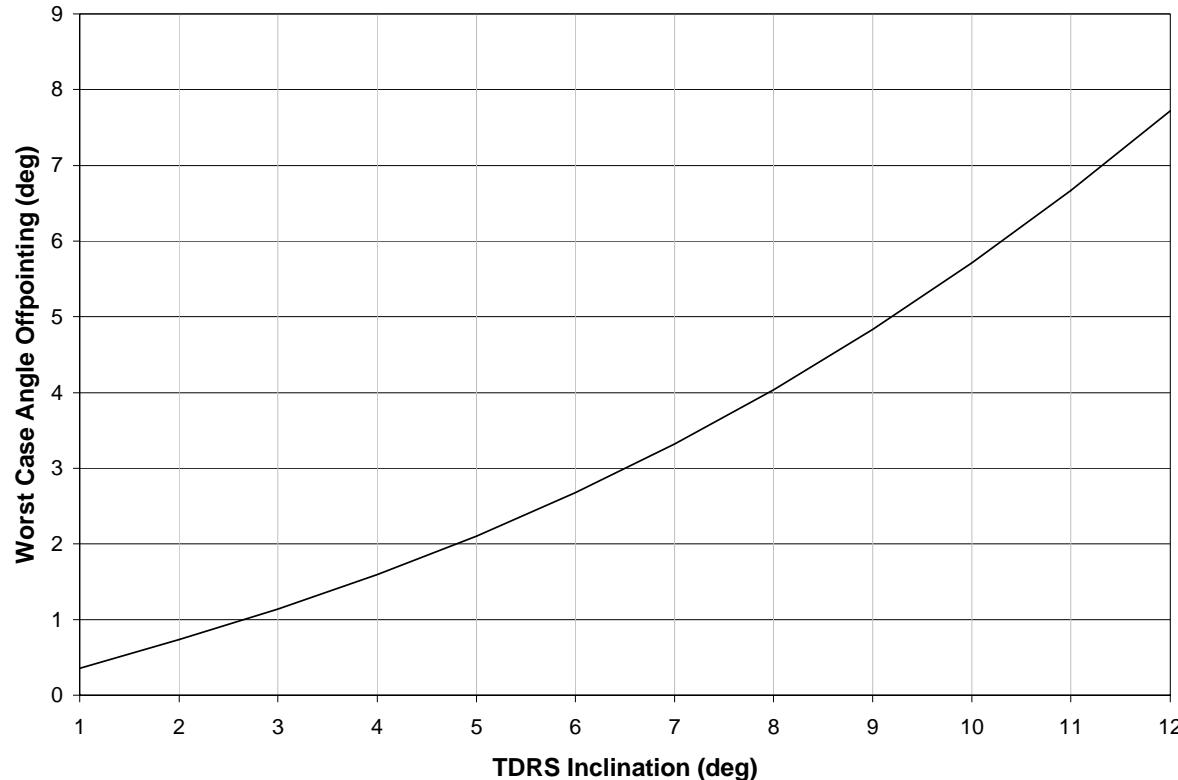
TDRS 'Figure 8' Orbit Worst Case Ephemeris Error

- TDRS GEO orbit effectively appears as a 'Figure 8' to LEO and terrestrial users so that ephemeris inaccuracies are bounded by this 'box'
- Question: Can DAS tolerate worst case ephemeris error within this 'bounded box' ?
- If yes, then would never need to replan for current day ops





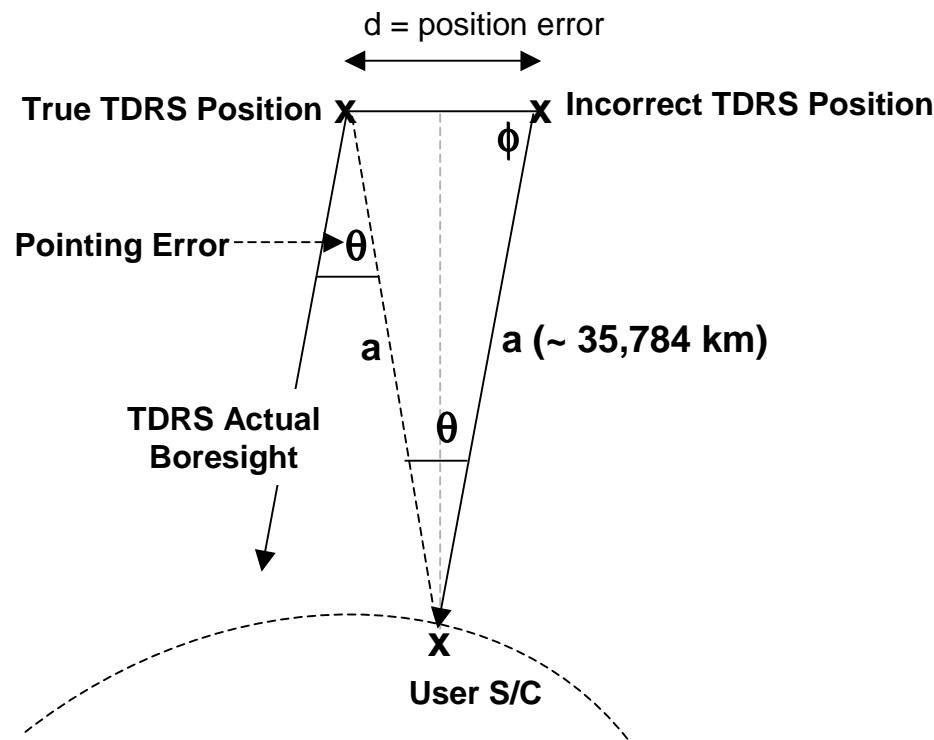
TDRS Offpointing vs Orbit Inclination (at Worst Case Ephemeris Error)



- Exceeds max 0.3° threshold offpointing even at $I = 1^\circ$
- Cannot tolerate worst case position errors for anticipated TDRS inclinations
- Must limit position error to some appropriate maximum value that ensures $< 0.3^\circ$ offpointing



Maximum Tolerable TDRS Ephemeris Error (Due to MA Antenna Off-pointing)



θ = TDRS Pointing Error

d = TDRS Position Error

$$\sin \theta/2 = (d/2)/a$$

$$d = 2a \times \sin \theta/2$$

$$d_{\max} = 2a \times \sin(0.15^\circ)$$

$$d_{\max} \sim 187 \text{ km}$$

Limit TDRS ephemeris error to < 187 km to limit pointing losses to < 0.1 dB



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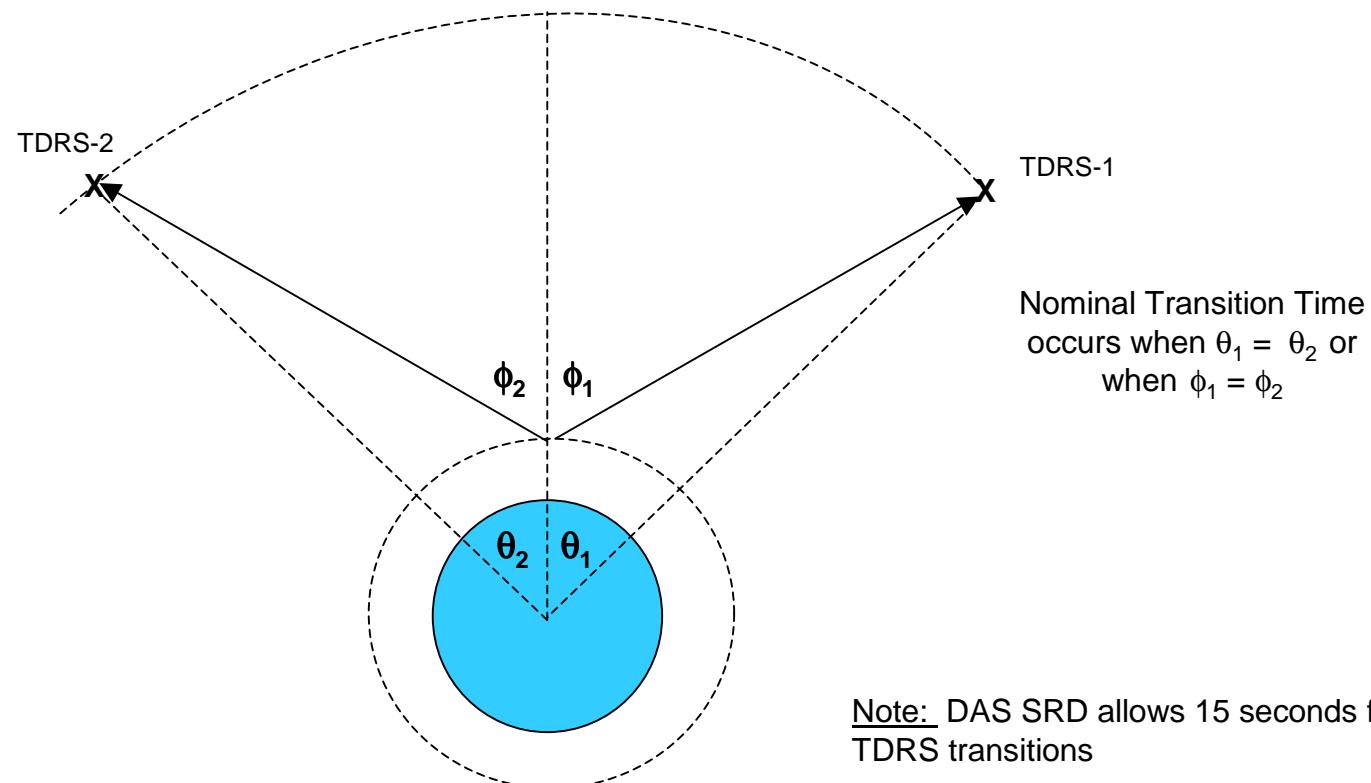
MA Antenna Offpointing

→ **TDRS Transition time**

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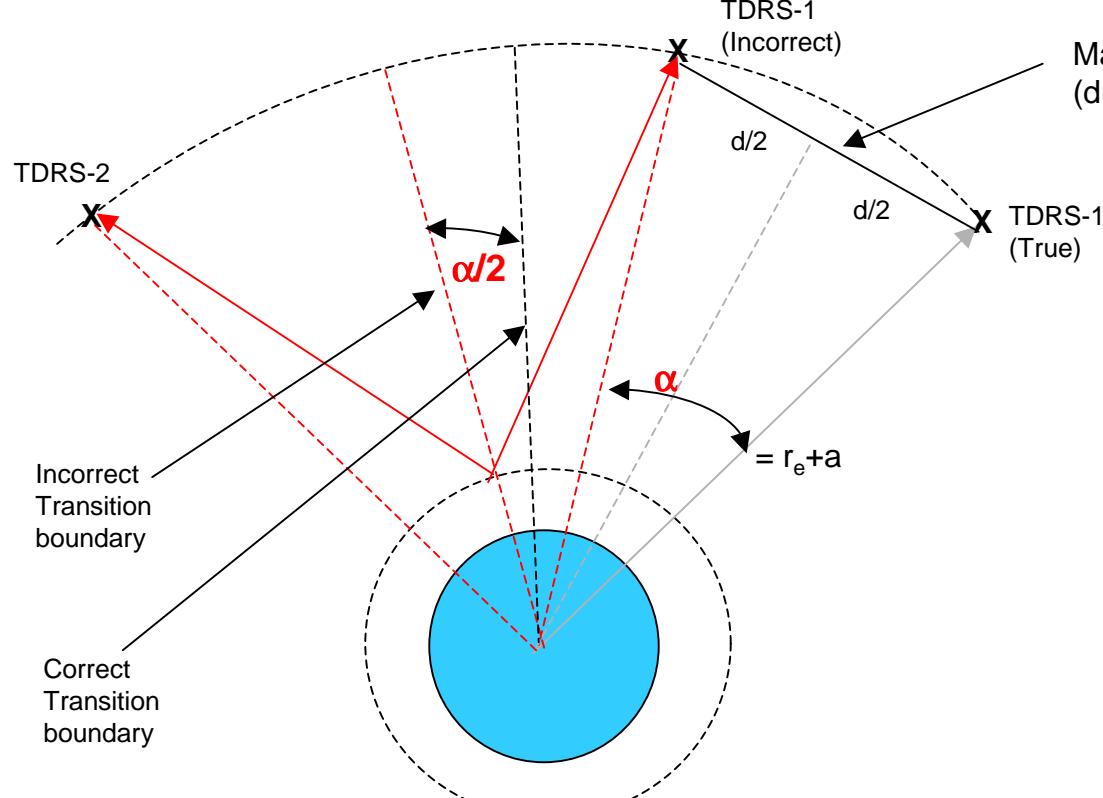


Nominal TDRS Transition Timing





TDRS Transition Timing (Error) (Due to TDRS Ephemeris Error)



- In this example, transition time (T_T) occurs later in User Orbit by angle $\alpha/2$
- $\alpha/2 \sim \sin^{-1}[(d/2)/(r_e+a)]$
- $\alpha_{\max}/2 = \sin^{-1}[(187/2)/(42162)]$
- $\alpha_{\max}/2 \sim 0.125^\circ$
- Delta time ~ 1.9 secs for 90 minute orbit
- Reasonable error based on 15 second transition time requirements (<7 secs required for demod acq time)



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TDRS Ephemeris Error on Tracking

- 2nd Order Tracking loop cannot track out Doppler Rate component
 - Residual Steady State error results

- Phase Error (degrees) due to Doppler Rate Error
$$= [(180/\pi) \times 1.77 \times R_D] / B_L^2 ; B_L = \text{Carrier Tracking Loop bandwidth} (> 10 \text{ Hz})$$

- Maximum Doppler Rate Error due to TDRS Ephemeris Error
 - Maximum Jerk = 0.02 m/sec³ (DAS SRD)
 - Effective worst case time offset in 90 minute orbit ~ 1.9 sec (Previous slides)
 - Maximum Doppler rate Error:
$$\sim 0.02 \text{ m/sec}^2 \times 1.9 \text{ sec} \times 7.625 \text{ Hz/(m/sec)} \sim 0.3 \text{ Hz/sec}$$

- Maximum Phase Error (deg)
$$< [(180/\pi) \times 1.77 \times 0.3 \text{ Hz/sec}] / 100 \text{ Hz}^2 \sim 0.3^\circ \text{ (minimal Impact)}$$

- Conclusion: as long as TDRS Ephemeris error < 187 km, impact on tracking is minimal